(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 October 2002 (31.10.2002)

PCT

(10) International Publication Number
WO 02/087012 A1

(51) International Patent Classification[7]: H01Q 1/38, 1/48, 1/24

(21) International Application Number: PCT/SE02/00720

(22) International Filing Date: 12 April 2002 (12.04.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0101427-3 24 April 2001 (24.04.2001) SE
60/289,966 9 May 2001 (09.05.2001) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

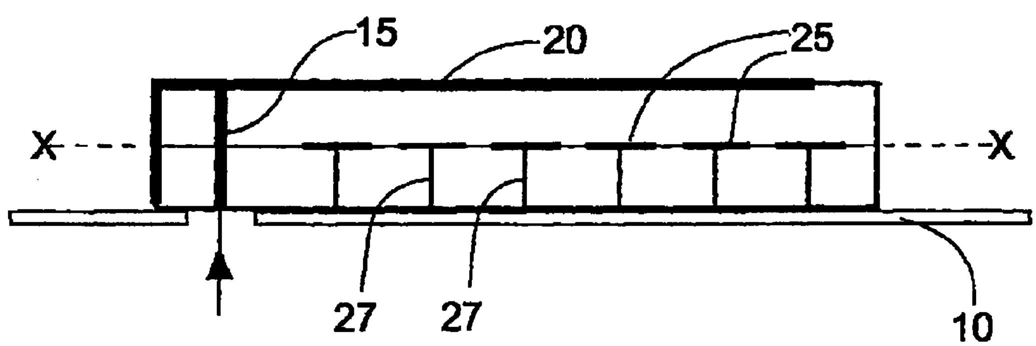
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: PIFA ANTENNA WITH HIGP STRUCTURE



(57) Abstract: An antenna device for a small communication module providing increased bandwidth as well as a method for obtaining such an arrangement are disclosed. The invention combines characteristics of Planar Inverted F Antennas (PIFA) and High Impedance Ground-Plane (HIGP) structures to increase the bandwidth of the PIFA by utilizing a Photon Band Gap (PGB) structure and additionally using an optimized counterpoise size. By inserting a high impedance ground-plane inside a Planar Inverted F Antenna (1) it is possible to increase the bandwidth of the antenna without increasing its height. By additionally optimizing the size of a present counterpoise (10) cooperating with the antenna device, a best possible bandwidth of the device is obtained. By the use of a PBG structure for the embedded high impedance ground-plane in combination with the matched counterpoise it is then possible to obtain a further increased bandwidth.

WO 02/087012 A1

PIFA Antenna with HIGP structure

TECHNICAL FIELD

The present invention relates to compact antenna devices and more particularly to a Planar Inverted F Antenna having inserted a high impedance ground-plane and being provided with a counterpoise of an optimized size as well as a method of achieving such a functional arrangement.

BACKGROUND

Wireless products of today and in the future must be miniaturized. The trend is to integrate all electronics into one module. Wireless products and their antennas must be miniaturized to be able to compete on the market of today. The limit in size of the system antenna will be dependent on the bandwidth of the antenna, according to Wheeler's small antenna formula. Therefore the necessary bandwidth of the system sets the smallest size of the antenna. The wireless products are often much smaller than the system wavelength. This will lead to that the antenna will induce a lot of currents on the rest of the conductors within the product. Therefore the whole product as a matter of fact acts as the antenna.

According to "IEEE Standard Definitions of Terms for Antennas" (see publication ISBN 1-55937-317-2, 1993) a counterpoise is a system of conductors, elevated above and insulated from the ground, forming a lower system of conductors of an antenna". Therefore counterpoise is a better word than ground-plane. In Bluetooth™ antenna design the resonance frequency and bandwidth of the reflected signal towards the output power amplifier are important design parameters.

Many Bluetooth™ products being developed at the moment use a Planar Inverted F Antenna (PIFA) for radiating the power into the air. The PIFA antenna is bandwidth limited and problems will occur regarding bandwidth requirements. By increasing the height of the antenna, it is possible to increase the bandwidth of the antenna. This is often not an attractive

alternative in product development due to changes in plastic case and product design-look.

There are found several documents disclosing solutions for improving the performance of an antenna by varying different characteristics of dielectric substrates or ground planes. U/S. Patent No. 5,541,613 discloses a broadband antenna system utilizing multiple Photonic Band Gap crystals (PBG) for increasing its power efficiency over a larger range of frequencies than prior antenna systems. Another document U.S. Patent No. 5,739,796 provides a multidimensional stacked Photonic Band Gap crystal structures improving the performance of current planar monolitic antennas and RF filters. The document describes a manner in which a PBG structure may be used to improve characteristics of an antenna. Among other things this substrate may be used to improve the bandwidth of the antenna.

A document U.S. Patent No. 5,406,573 discloses a periodic dielectric structure for production of Photonic Band Gap and a method for producing a PBG substrate which can be used for making wave-guides, since such a material is an ideal reflector at the band gap frequencies. In this way the output efficiencies of antennas could be improved.

However there is still a demand for an efficient antenna design which fulfils requirements set for small modules like Bluetooth™ products. Particularly no overall solution has been seen, which takes into account all fundamental limitations and variations in antenna performance due to the size of the particular product.

SUMMARY OF THE INVENTION

The present invention combines characteristics of Planar Inverted F Antennas (PIFA) and High Impedance Ground-Plane (HIGP) structures to increase the bandwidth of the PIFA by utilizing a Photonic Band Gap (PGB) structure and an optimized counterpoise size.

By inserting a high impedance ground-plane inside a Planar Inverted F Antenna it is possible to increase the bandwidth of the antenna without increasing its height. Therefore this is an attractive alternative in product development due to no changes outside the antenna space. By additionally optimizing the size of a present counterpoise cooperating with the antenna device, a best possible bandwidth of the device is obtained.

As the bandwidth increases with the substrate thickness and knowing the properties of a Photonic Band Gap structure it is then possible to further increase the bandwidth by using such a PBG structure for an embedded high impedance ground-plane combined with the matched counterpoise.

A counterpoise antenna arrangement according to the present invention is set forth by the independent claim 1, and further embodiments of the invention are set forth by the dependent claims 2 to 4.

Furthermore a method for obtaining counterpoise antenna arrangement according to the present invention is set forth by the independent claim 5, and further embodiments of the method according to the invention is set forth by the dependent claims 6 to 8.

SHORT DESCRIPTION OF THE DRAWINGS

The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings wherein like reference numerals refer to corresponding elements and in which:

FIG. 1 illustrates reflection of signal from an antenna back to a power amplifier due to improper matching;

FIG. 2 illustrates an illustrative embodiment of a Planar Inverted F Antenna positioned on a plate forming a counterpoise;

FIG. 3 illustrates in a plan view the Planar Inverted F Antenna of FIG. 2 with its counterpoise;

FIG. 4 is a vertical cross section through the antenna according to FIG. 2 indicating an embedded high impedance ground-plane structure, and indicating a horizontal cross section X-X through the structures;

FIG. 5 illustrates a horizontal cross section along a line X-X of the Planar Inverted F Antenna of FIG. 4; and

FIG. 6 illustrates an example of dimensions of a PBG Planar Inverted F Antenna, PIFA;

FIG. 7 is a contour map illustrating antenna bandwidths between 50 MHz and 150 MHz using steps of 25 MHz between adjacent contours as a function of length and width of a present counterpoise when utilizing a PIFA arrangement according to the present invention at a frequency of 2,45 GHz.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a standard situation with a RF power amplifier connected to an antenna intended to irradiate the radio frequency power. Typically there may be only a very limited bandwidth, BW, for which the output of the power amplifier experiences a good match and when the outputted power from the amplifier will be radiated by the connected antenna. Changing the operation frequency just slightly may result in a mismatch between the amplifier and the antenna. Then a part of the power will be reflected back towards the amplifier. This means a power loss, which usually will be seen as an additional heating of the amplifier, besides resulting in a low efficiency at the particular antenna device.

Consequently, there is a desire to obtain a largest possible bandwidth of an antenna to have the smallest possible amount of power reflected back from the antenna to the power amplifier. Therefore, for instance in a Bluetooth™ antenna design, the resonance frequency and bandwidth of the antenna for minimum reflected signal towards the output power amplifier are very important design parameters.

Seeing that the bandwidth increases with the substrate thickness and knowing the properties of a Photonic Band Gap structure (PBG) it will be possible to increase the bandwidth by using such a PBG structure (as high impedance ground-plane). Since many Bluetooth Planar Inverted F Antennas are manufactured by two 60 mil (≈1.5 mm) layers, glued together by an adhesive film, it is possible to implement a PBG structure into a design according to Figure 2. The size of the PBG structure can vary. It is dependent on the dielectric constant, number of metal layers and the thickness of the layers. A higher dielectric constant always will result in a thinner PBG structure.

According to the present inventive idea a PIFA radiator **20** with its generally non-conducting carrier substrate **1** is placed on a module which in an illustrative embodiment is shaped as a rectangle or a square, which will then act as a counterpoise. However, the counterpoise may form an arbitrary shaped base in line with a general module design. Figure 2 illustrates an illustrative embodiment of a Planar Inverted F Antenna **20** positioned on a plate **10** forming a counterpoise. The plate **10** may further carry additional components like for instance resistors, capacitors, semiconductor components and/or a number of integrated circuits **12** as illustrated in Figure 2. The circuits **12** may preferably be positioned at the lower surface of plate **10**, while the entire upper surface constitutes a conducting surface screening the circuitry underneath.

Figure 4 is a vertical cross section through the PIFA device according to Figure 2, indicating an embedded high impedance ground-plane structure

25, and indicating a horizontal cross section X-X through the structure **25**. As indicated the high impedance ground-plane structure is connected to the plate constituting the counterpoise 10. Additionally, the PIFA structure is provided with a feeding pin **15**, which in turn in the present embodiment via a through hole in the counterpoise **10** is connected to an output terminal of a power amplifier (not shown) supplying the radiator element **20** with radio frequency power to be radiated.

In Figure 5 is illustrated a horizontal cross section along a line X-X of the Planar Inverted F Antenna of FIG. 4 seen from below. The extension of the radiator **20** at the top of the substrate material **1** is marked by a shaded area. The single layer embedded high impedance ground-plane structure **25** is seen with its connections **27**, which run down to the conducting counterpoise plate **10**. In an example, as demonstrated in Figure 6, the following dimensions may be used for a single layer embedded structure **25**. According to established dimensioning rules for $\lambda/4$ dimensions with an assumed wavelength of 120 mm corresponding to the 2.45 GHz band and a thickness of layer I, t_1 = 2 mm and a thickness of layer II, t_2 = 2 mm we obtain:

$$L_3 = 120/\left(4 \cdot \sqrt{\varepsilon_{r1}}\right) = 30 \text{ mm}$$

$$L_2 = 0.5 \text{ mm} \quad \text{(approximately)}$$

$$L_1 = 120/\left(4 \cdot \sqrt{\varepsilon_{r2}}\right) - t_1 - L_2 = 5.0 \text{ mm}$$

in which is used a dielectric constant ε_{r1} = 1 for layer I and a dielectric constant ε_{r2} = 16 for layer II.

For a one-layer PBG structure it is important to use a low dielectric constant in layer 1 to lengthen L3 and a high dielectric constant in layer 2 to shrink L1. The same dielectric constant can be used in both layers 1 and 2 by use of a multi-layer PBG structure.

Now having a geometry as indicated in Figure 3 with the PIFA placed onto, in the present case, with the in this case rectangular shaped module plate

acting as counterpoise a next step would be to find optimum values for the width W and length L of the counterpoise to obtain a good bandwidth of the radiating device. Computerized tools like Ansoft HFSS, Optimetrics and MATLAB may typically be used to evaluate how the bandwidth, resonance frequency and feed point are varying with counterpoise width and length to thereby confirm an improved module antenna design.

In an illustrative example according to Figure 2 for a device operating for instance at 2.45 GHz, being a typical frequency for a design for a Bluetooth™ application, the antenna block **1** may have a length of about 20 mm, a width about 4 mm and a thickness about 3 mm.

In Figure 7 is illustrated a simplified plot of the output from a computer calculation of a matched counterpoise using the present suggested build-up of the PIFA radiator device for operation at about 2.45 GHz and utilizing the suggested computerized tools. The plot in Figure 7 is from practical reasons just formed as a contour map covering bandwidths from about 50 MHz to about 150 MHz in steps of 25 MHz. This means that for instance a contour line marked with 125 means that within this contour the bandwidth is 125 MHz or better and outside the contour the bandwidth is less than 125 MHz. The calculation in reality gives an even more detailed map which may be visualized as a color plot of bandwidths between 50 and 150 MHz for instance presenting a resolution of 10 MHz or better.

The width W of the counterpoise **10** was in the illustrative calculation varied in steps of 10 mm from 20 mm up to 200 mm and the length L of the counterpoise was varied in steps of 10 mm from 10 mm up to 200 mm. The plot produced represents the antenna bandwidth by looking at the reflected signal from the antenna as a function of width and length of an actual counterpoise. For a length $L \approx 40$ mm and a width $W \approx 20$ mm of the counterpoise it is seen in Figure 7 that a bandwidth $BW \geq 125$ MHz for the particular antenna may be obtained. It is also noted from Figure 6 that for a counterpoise having a width of the order of 50 mm and a length of the order

of 10 - 20 mm a bandwidth BW $\geq$150 MHz would be obtained. It should also be noted, that for a width of the order 60 mm and a length from about 50mm to 200 mm a bandwidth of more than 125 MHz will be obtained, while decreasing or increasing the width by about 10 mm or more will drastically lower the bandwidth of the antenna.

Thus by using the sketched method of evaluating the design, a proper size of the counterpoise can be found in combination with the present PIFA radiator device for operation at, for instance, 2.45 GHz with an optimum operating bandwidth. Consequently, the size of for instance a Bluetooth™ product should follow any of the combinations of measures obtained from such a calculation of a matched counterpoise according to the present disclosure in order to obtain a desirable best possible bandwidth.

The invention has been described functionally in detail with reference to drawings relating to an illustrative embodiment. The possibility of an arbitrary combination of different embodiments in order to produce an efficient and appropriate device is also intended to lie within the scope of the invention, which is defined by the appended claims.

CLAIMS

1. An antenna device for a small communication module providing increased bandwidth comprising

a Planar Inverted F Antenna device structure comprising an antenna radiator provided with a feeding pin on a non-conducting substrate, said Planar Inverted F Antenna device structure being positioned onto an arbitrary shaped base forming a counterpoise;

an inserted high impedance ground-plane within said Planar Inverted F Antenna structure, said inserted high impedance ground-plane forming a Photonic Band Gap structure, thereby increasing the bandwidth without increasing the height of the Planar Inverted F Antenna;

whereby the arbitrary shaped base forming the counterpoise is matched in length and width, thereby to obtain a minimum of reflected power from the antenna device.

2. The antenna device according to claim 1, wherein said high impedance ground-plane of the Planar Inverted F Antenna device structure comprises a single layer structure inside the non-conducting substrate, said high impedance ground-plane comprising one or several portions connected to the matched counterpoise.

3. The antenna device according to claim 1, wherein a high impedance ground-plane of the Planar Inverted F Antenna device structure comprises a multi-layered structure inside the non-conducting substrate.

4. The antenna device according to claim 2, wherein said counterpoise at the same time also constitutes the communication module containing, on either side or both sides, further components of a module arrangement.

5. The antenna device according to claim 3, wherein said counterpoise at the same time also constitutes the communication module containing, on either side or both sides, further components of a module arrangement.

6. A method for producing a microwave antenna device for a small communication module providing a desired increased optimum bandwidth comprising the steps of:

producing a Planar Inverted F Antenna device structure, for operation at a desired microwave frequency, said Planar Inverted F Antenna device structure having within its structure a high impedance ground-plane structure forming a Photonic Band Gap structure, thereby increasing bandwidth without increasing a height of the Planar Inverted F Antenna device structure;

arranging said Planar Inverted F Antenna device structure onto an arbitrary base plate forming a counterpoise cooperating with the Planar Inverted F Antenna device structure, whereby the length and width of the counterpoise is matched in order to obtain a maximum bandwidth of the antenna device.

7. The method according to claim 6, comprising the further step of forming the high impedance ground-plane of the Planar Inverted F Antenna device structure as a single layer structure inside a non-conducting substrate.

8. The method according to claim 6, comprising the further step of forming the high impedance ground-plane of the Planar Inverted F Antenna device structure as a multi-layered structure inside a non-conducting substrate.

9. The method according to claim 6, comprising the further step of using a computerized calculation for evaluating how bandwidth varies with resonance frequency and feed point and as a function of width and length of the counterpoise to thereby determine an optimum measure of the counterpoise.

10. The method according to claim 7, comprising the further step of using a computerized calculation for evaluating how bandwidth varies with resonance frequency and feed point and as a function of width and length of the counterpoise to thereby determine an optimum measure of the counterpoise.

11. The method according to claim 8, comprising the further step of using a computerized calculation for evaluating how bandwidth varies with resonance frequency and feed point and as a function of width and length of the counterpoise to thereby determine an optimum measure of the counterpoise.

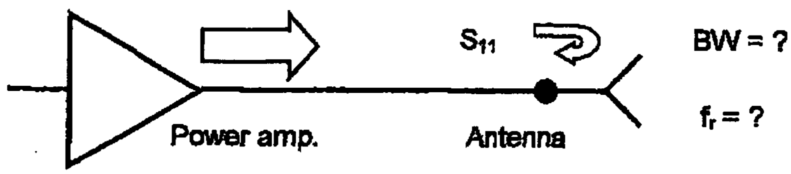


Fig. 1

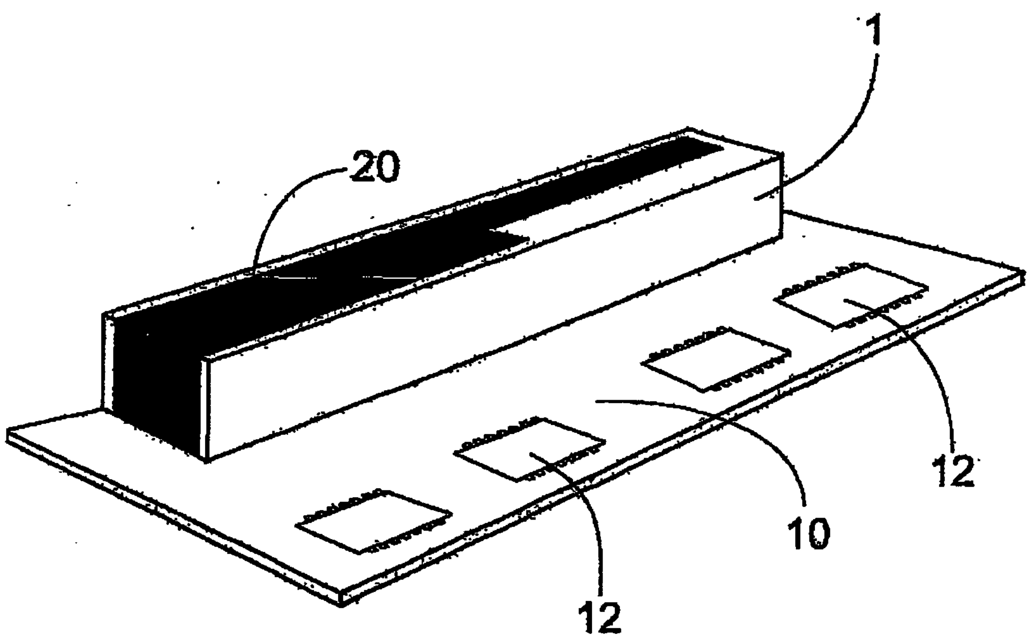


Fig. 2

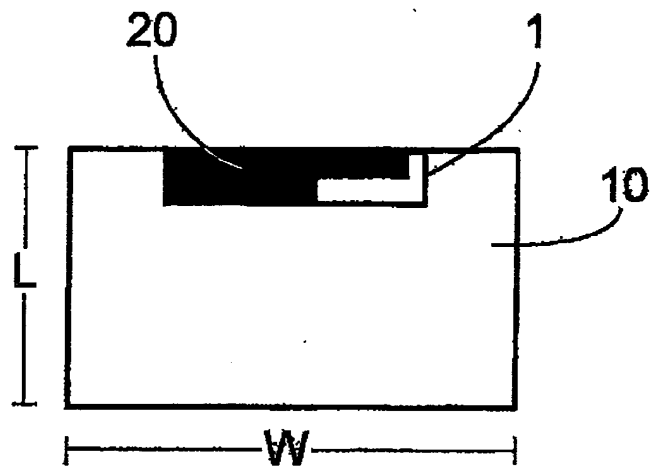


Fig. 3

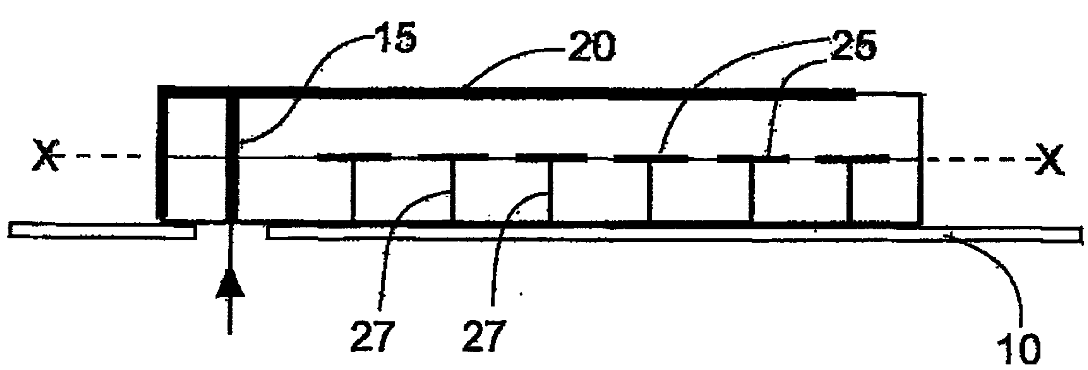


Fig. 4

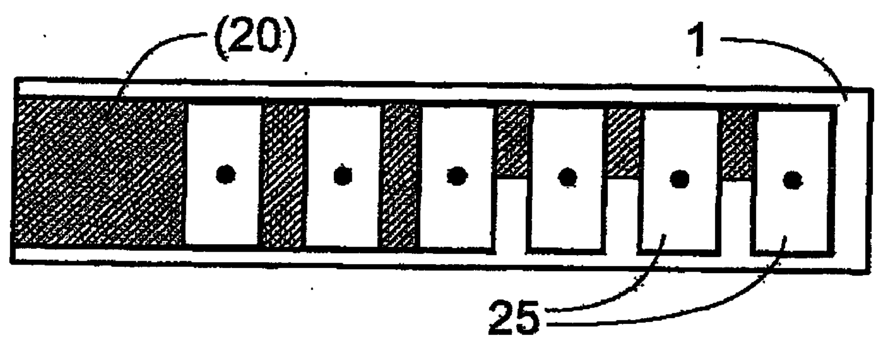


Fig. 5

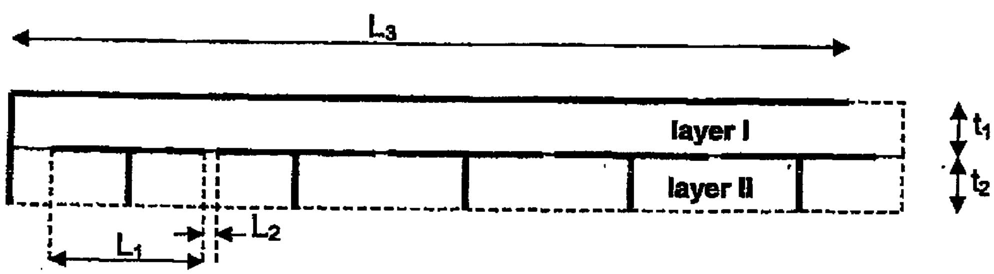


Fig. 6

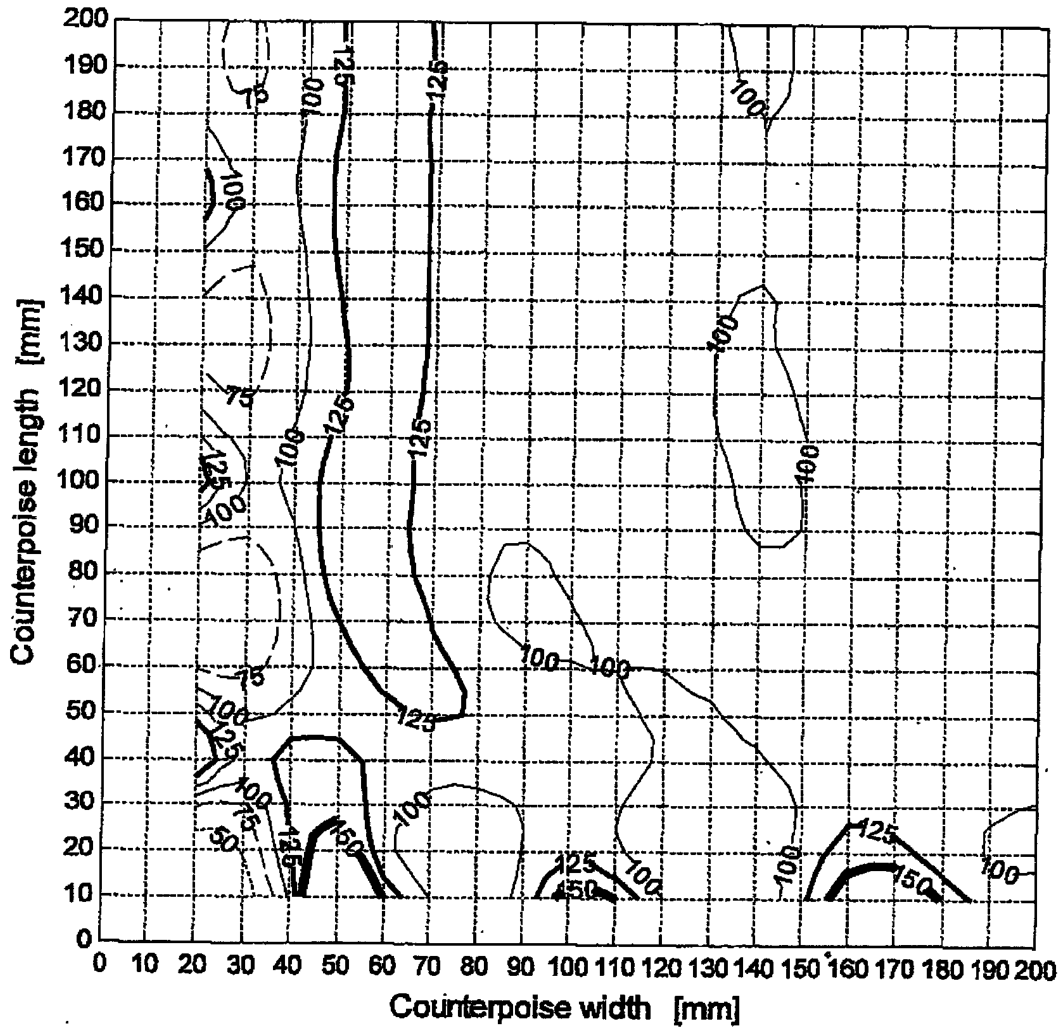

Counterpoise length [mm]
Counterpoise width [mm]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
50
75
100
125
150

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00720

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01Q 1/38, H01Q 1/48, H01Q 1/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9950929 A1 (THE REGENTS OF THE UNIVERSITY OF CALIFORNIA ET AL), 7 October 1999 (07.10.99), page 14, line 19 - page 15, line 9; page 16, line 6 - line 14; page 19, line 4 - line 22 --	1-11
A	US 6111544 A (Y. DAKEYA ET AL), 29 August 2000 (29.08.00), column 13, line 36 - line 62, figures 1-15, abstract --	1-11
A	2001. Eleventh International Conference on (IEE Conf. Publ. No. 480), Antennas and Propagation, pages 719-723, vol. 2, 17-20 April 2001, Salonen P. et al: "A low-cost 2.45 GHz photonic band-gap patch antenna for wearable systems". --	1-11

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 August 2002	20 -08- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Marianne Dickman/SN Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00720

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, abstract of JP 11-340719 A (MITSUBISHI MATERIALS CORP), 10 December 1999 (10.12.99) --	1-11
A	Patent Abstracts of Japan, abstract of JP 12-101333 A (SONY CORP), 7 April 2000 (07.04.00) --	1-11
A	Patent Abstracts of Japan, abstract of JP 10-322124 A (NIPPON ANTENNA CO LTD), 4 December 1998 (04.12.98) -- --------	1-11

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE 02/00720

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9950929 A1	07/10/99	CA 2323610 A	07/10/99
		DE 1075712 T	23/08/01
		EP 1075712 A	14/02/01
		ES 2160561 T	16/11/01
		JP 2002510886 T	09/04/02
		US 6262495 B	17/07/01
US 6111544 A	29/08/00	DE 19904724 A	02/09/99
		JP 2000101335 A	07/04/00
		SE 9900407 A	14/08/99